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THYRISTOR BEHAVIOR AT CRYOGENIC TEMPERATURES

R.Trendler and R.Winje

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ABSTRACT

Several types of thyristors have been dynamically tested at temperatures ranging from 293°K to 4.2°K to determine an effective lower temperature limit of operation. The types of thyristors tested, experimental apparatus, and test results are presented.

INTRODUCTION

As superconducting systems become more prevalent, the likelihood of semiconductor operation at cryogenic temperatures is increased. To study one aspect of this, several thyristors were chosen for examination. Because of dewar space limitations four thyristors were chosen from those in use at Fermilab. Two "hockey puck" types; Westinghouse T920, Westinghouse T72C, and two stud mount types; International Rectifier 71RA, General Electric C185B, were selected. The significant parameters of these devices are listed in Table I. The thyristors were appropriately clamped or fastened to heat sinks, instrumented with thermocouples and germanium resistors, thermometers and dynamically tested with a Tektronix 576 curve tracer. Six temperatures were used in the test including room temperature tests at various times between cold tests.

EXPERIMENT

The total test fell into three individual tests; 1) 77°K liquid nitrogen immersion test; 2) 4.2°K liquid helium immersion test; and 3) (a 20°K, 30°K, 50°K) helium vapor test.

In test 1), the devices were merely immersed in liquid nitrogen and tested; in test 2), the devices were placed in a dewar and then cooled by introducing liquid helium into the dewar. The devices in both tests were cooled quite rapidly. In test 3), a thermally insulated region containing the thyristors, heatsinks, thermocouples, germanium resistors, and heating resistors was placed in a dewar. The helium transfer line was extended so as to introduce liquid helium below the isolated region. All test leads were brought out through the header assembly. By controlling a current through the header resistors the temperature of the region could be roughly controlled; i.e., ±2°K.

TESTS

The thyristor parameters which were studied included; 1) gate sensitivity, 2) gate voltage and currents, and 3) forward and reverse blocking voltages and the forward voltage anode to cathode voltage drop.

RESULTS

The detailed test results are shown in Table II.

From room temperature to 50°K the thyristors did not fail and only suffered a small loss of their rated room temperature blocking voltages. The gate current required for conduction was lower than that at room temperature in three of the devices and showed a small unexplained increase in the Westinghouse T72C.

After the devices were tested at 77°K, they were retested at room temperature. The device identified as the Westinghouse WT920 (#1) failed in that its forward and reverse blocking voltages capability was depleted. Subsequently, the device case was opened. A careful visual examination showed numerous small cracks and voids in the varnish used to seal the tapered edge of the fusion. The failure of the varnish caused the degradation in the blocking voltages. This problem could undoubtedly be solved by using a sealing material which retains more of its room temperature pliability.

Testing at temperatures of 30°K and below demonstrated that the thyristors could not be gated with the twenty volt or two ampere gate drive which was available in the test set. In most cases, the forward and reverse blocking voltage capability was degraded, but with the exception of the WT920, all the thyristors recovered this capability after they were warmed to room temperature.

The IR71RA was thermally shocked to 77°K from 293°K with no apparent degradation in its characteristics. This test was repeated ten times.

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TABLE I

PARAMETER	W920T	WT72C	IR71RA	GEC185B
Repetitive Peak off State Voltage	1200V	1800V	1400V	200V
Repetitive Peak Reverse Voltage	1200V	1800V	1400V	200V
Non-Repetitive Peak Reverse Voltage	1300V	2150V	1650V	300V
RMS on State Current	1000A	700A	110A	235A
Average Current			70A	
Peak One Cycle Surge I	16000A	7500A	1600A	3500A
di/dt	800A/μs	600A/μs	300A/μs	100A/μs
dv/dt (min)	200V/μs	300V/μs	200V/μs	200V/μs
I_H Holding Current (non)			500 ma	500 ma
DC Gate Trigger Current-40°C			35 ma	500 ma
+125°C		150 ma		250 ma
I_J=25C	200 ma			
DC Gate Trigger Voltage	3V	3V	3V	3V

TABLE II

LOW TEMPERATURE THYRISTOR TEST RESULTS

DEVICE	PARA-METER	293°K	77°K	293°K	6/3 4.2°K	6/3 293°K	6/10 293°K	6/10 20°K	6/10 30°K	6/10 50°K	6/11 293°K
WT72C	BVF	>1700	1560	>1700	70						
	BVR	>1700	1660	>1700	550	Failed					
#1	IGT	15na	22	15	NF						
	VGT	0.45	1.15	0.48	NF						
	VT	0.85	1.3	0.85	10						
WT72C	BVF						>1680	500		400	>1700
#2	BVR						>1680	100		350	>1700
	IGT						230	NF	NF	6	205
	VGT						0.82	NF	NF	1.6	0.78
	VT						0.82	12		1.5	0.8
WT920	BVF	1440	1100								
	BVR	950	700	Failed							
#1	IGT	90	33.5								
	VGT	0.7	1.9								
	VT	1.2	1.3								
WT920	BVF			1160	11						
	BVR			1300	1120	Failed					
#2	IGT			88	NF						
	VGT			1.54	NF						
	VT			1.0	7						
WT920	BVF						1500	200			200
	BVR						1500	1140			1500
#3	IGT						104	NF	NF	0.2	92
	VGT						1.64	NF	NF	4.5	1.6
	VT						0.96	6		1.2	0.98
IR71RA	BVF	1500	1200	1500	170	1500					
	BVR	>1500	1350	>1500	1400	>1500	Failed				
#1	IGT	47	8.75	48	NF	49					
	VGT	0.5	1.75	0.8	NF	0.9					
	VT	0.8	1.3	0.8	20	1.0					
IR71RA	BVF						1540	600			1530
	BVR						1680	600			1620
#2	IGT						72	NF	NF	96	84
	VGT						0.7	NF	NF	20	1.0
	VT						0.9	16		1.6	0.96
GEC185B	BVF	400	300	400	100	400	400	350			400
	BVR	650	600	650	370	650	650	700			650
	IGT	54	7.5	65	NF	68	63	63	NF	NF	63
	VGT	1.0	1.9	1.0	NF	1.4	1.3	NF	NF	NF	1.3
	VT	1.2	1.8	1.2	20	1.1	1.08	16			1.08

BVF = forward avalanche voltage at 1 ma base open

BVR = Reverse avalanche voltage at 1 ma base open

IGT = Gate current to fire with 6 volts anode to cathode

VGT = Gate voltage to fire with 6 volts anode to cathode

VT = Forward voltage when fired for 500 ma $\leq I_T \leq$ 250 ma where I_T = forward current

NF = No fire